Impact of the Number of Blood Pressure Measurements on Blood Pressure Classification in US Adults: NHANES 1999–2008

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Clinical guidelines recommend averaging ≥2 blood pressure (BP) measurements on each visit. Only one BP is measured on many clinical visits, especially if the value is <120/<80 mm Hg, ie, normal. The impact of this practice on accurate assignment of BP category is incompletely defined. Data were analyzed from 22,641 adults 18 years and older who had 3 BP readings in the National Health and Nutrition Examination Surveys 1999–2008. BP category defined by initial measurement was compared with the category determined by mean of the first and second, first through third, and second and third readings. Among 8553 nonhypertensive patients with initial BP <120/<80 mm Hg, 2.9%, 3.3%, and 6.7%, respectively, were reclassified as prehypertensive, ie, BP 120–139/80–89 mm Hg, and two patients as stage 1 hypertension (140–159/90–99 mm Hg). In 733 treated hypertensive patients with initial BP <120/<80 mm Hg, 5.1%–8.9% were reclassified as prehypertensive and only one patient as hypertensive. Among nonhypertensive and hypertensive patients with initial BP in the prehypertensive range, 8.0%–23.6% were reclassified as normal. Among stage 1 and 2 hypertensive patients based on initial BP, 18.2%–33.5% were reclassified to lower BP categories. By multivariable logistic regression, older age and higher systolic and diastolic BP were associated with reclassification to a lower BP category. In nonhypertensive and hypertensive patients with normal initial BP values, one BP measurement appears adequate as <10% are re-classified as prehypertensive and <0.5% as hypertensive. In contrast, patients with an initial BP above normal are often reclassified to a lower category, which supports recommendations for additional measurements. *J Clin Hypertens (Greenwich)*. 2012;14:751–759. ©2012 Wiley Periodicals, Inc.

There is a discrepancy between the number of blood pressure (BP) measurements recommended during a usual office encounter and the number performed in clinical practice. The American Heart Association's (AHA's) recommendation for BP measurement is that "a minimum of two readings should be taken . . . and the average of those readings should be used to represent the patient's BP."[1] All hypertension treatment trials use mean BPs to assess control, with most trials using the mean of two BP measurements.[2,3] In the National Health and Nutrition Examination Survey (NHANES), three BPs were generally obtained. The NHANES analytic and reporting guidelines recommend using the mean of the second and third BPs.[4]

The realities of busy primary care practice demand more rapid preparation for the physician-patient encounter than multiple BPs, performed routinely, would allow. In the southern California Permanente Kaiser Permanente Medical group, a majority of more than 2,300,000 BPs recorded by office staff each month are performed as single determinations.[5] According to a national ambulatory medical care survey in 2008, the most commonly recorded *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) disease diagnosis code was 401 for essential hypertension.[6]

The discrepancy in the number of BP measurements recommended in guidelines and the number performed in clinical practice raises questions. For example, are there patient care consequences for taking a single BP in the primary care office setting? Specifically, how often would the treatment category change if multiple BPs were obtained in all cases? In order to examine and isolate the effect of single vs multiple BP measurements on BP category, it would be ideal to have a methodology that obviates the multiple flaws and inconsistencies in BP technique, which can lead to variability. NHANES represents a large database of multiple BPs performed with protocol accuracy and consistency in a cross-sectional sample of the US civilian population. Thus, we used NHANES data to address questions raised.

METHODS

NHANES 1999–2008 were conducted by the Centers for Disease Control and Prevention National Center for Health Statistics (NCHS). NHANES volunteers were selected using stratified, multistage probability sampling of the noninstitutionalized US civilian population. All adults provided written informed consent approved by the NCHS institutional/ethics review board.[7,8]

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Patients
Only adults 18 years and older in NHANES 1999–2008 with three BP measurements were included.

BP Measurement
BP in NHANES 1999–2008 was measured by trained physicians using mercury sphygmomanometry and appropriately sized arm cuffs after volunteers rested for 5 minutes while seated.[4,9]

Definitions
Race/ethnicity was determined by self-report and separated into non-Hispanic white (white), non-Hispanic black (black), Hispanic, and other race/ethnicity.[10]

Prevalent hypertension was defined as mean systolic BP ≥140 mm Hg and/or mean diastolic ≥90 mm Hg and/or affirming participants were currently taking prescription medication to lower BP.[4,8,11]

Defining Concomitant Risk Factors
Diabetes was defined by a positive response to the questions, "Have you ever been told by a doctor that you have diabetes?" and/or "Are you now taking insulin?" or "Are you now taking diabetes pills to lower your blood sugar?" The definition did not include patients with only fasting plasma glucose ≥126 mg/dL, ie, "undiagnosed diabetes."[4,11,12]

Current smoking was defined as a response of "yes" to the question "Have you smoked at least 100 cigarettes in your entire life?" and "every day" or "some days" to the household survey question "Do you now smoke cigarettes?" Former smoker was defined by a "yes" answer to the first of the above-mentioned questions and "not at all" to the second. Nonsmoker was defined by a "no" response to the first question.[13]

Comorbid Conditions
Chronic kidney disease ([CKD] nephropathy) was defined as estimated glomerular filtration rate (eGFR) <60 mL/1.73 m^2/min or urine albumin:creatinine ≥300 mg/g.[14,15] Serum creatinine values were adjusted to facilitate comparisons of eGFR across surveys.[16] Coronary heart disease (CHD) was defined by a positive response to the question, "Has a doctor ever told you that you had a heart attack," and/or angina according to the Rose and colleagues[17] questionnaire. Stroke and chronic heart failure were defined by positive responses to the questions, "Has a doctor ever told you that you had a stroke/congestive heart failure," respectively?[18,19]

Data Analysis
The NHANES Analytic and Reporting Guidelines were followed.[4,10] SAS callable SUDAAN version 9.0.1 (SAS Institute Inc, Cary, NC) was used for all analyses to account for the complex NHANES sampling design. Standard errors were estimated using Taylor series linearization.

Means and 95% confidence intervals (CIs) for continuous variables were calculated using the DESCRIPT procedure; the distributions (percentages and 95% CIs) of the categorical variables in each of BP category were computed from the CROSSTAB procedure. The CROSSTAB procedure was also used to reckon misclassification between using the first BP and the mean of ≥2 BP measurements. To identify covariates influencing reclassification to a different BP category, the MULTILOG procedure was utilized to fit the generalized logit model. The dependent variable was a categorical variable with three levels (positively reclassified [higher category, eg, normal to prehypertension], negatively reclassified [lower category, eg, stage 2 to stage 1 hypertension], and nonreclassified [same category]). The class orders (categories) from high to low are stage 2, stage 1, prehypertension, and normal BP. The univariable and multivariable odd ratios and 95% CIs of each covariate for positive and negative reclassification vs nonreclassification were calculated. Statistical significance was defined by nonoverlapping 95% CIs.

RESULTS
The process for selecting patients included is summarized in Figure 1. Patients 18 years and older in NHANES 1999–2008 with three measurements of systolic and diastolic BP were selected. From 25,606 adults in NHANES 1999–2008 with at least one BP measurement, 22,641 (88.4%) had three systolic and diastolic BP values.

The BP category was determined by the mean of the second and third BP values during the clinical evaluation for NHANES (Table I).[4,20] Systolic BP declined with repeated measurement across all BP categories, whereas diastolic BP did not. Age, the percentage of patients who were black, overweight or obese, hyper-

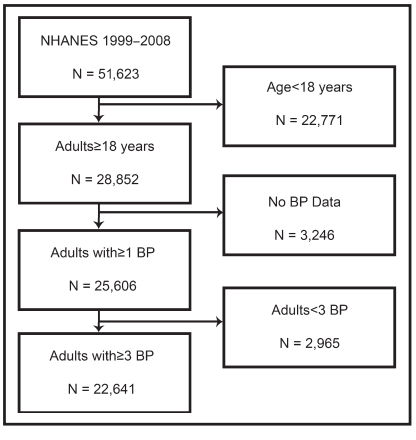

FIGURE 1. The number of individuals in the National Health and Nutrition Examination Surveys (NHANES) 1999–2008 reflects the sum of NHANES 1999–2000 (N=9965), 2001–2002 (N=11,039), 2003–2004 (N=10,122), 2005–2006 (N=10,348), 2007–2008 (N=10,149). The process is depicted for determining the study sample of adults with three blood pressure (BP) values.

TABLE I. Descriptive Characteristics of NHANES Patients by JNC 7 Blood Pressure Category

Variables	Normal BP[a]	Pre-HTN	Stage 1 HTN	Stage 2 HTN
No/%	10577/47.7 (46.5–48.9)	7844/36.2 (35.2–37.2)	2927/13.5 (12.8–14.2)	1293/4.8 (4.4–5.2)
Hypertension to normal	988/4.2 (3.8–4.6)	1882/7.6 (7–8.1)		
Age, y	38.9 (38.3–39.5)	47.1 (46.5–47.6)	56.0 (55.0–56.9)	63.2 (62.0–64.4)
Male, %	41.2 (40.0–42.3)	58.7 (57.5–59.9)	52.2 (49.8–54.5)	39.4 (36.1–42.7)
Female, %	58.8 (57.7–60.0)	41.3 (40.1–42.5)	47.8 (45.5–50.2)	60.6 (57.3–63.9)
NH white, %	70.7 (67.8–73.4)	73.6 (70.9–76.1)	73.5 (70.0–76.7)	67.6 (62.5–72.2)
NH black, %	9.4 (8.2–10.9)	10.7 (9.1–12.5)	12.9 (10.7–15.5)	17.2 (13.6–21.5)
Hispanic, %	15.2 (13.2–17.5)	11.1 (9.2–13.3)	9.3 (7.3–11.7)	10.9 (7.8–14.9)
Others, %	4.7 (4.0–5.5)	4.7 (3.9–5.5)	4.3 (3.4–5.6)	4.4 (2.7–7)
First SBP, mm Hg	110.0 (109.8–110.3)	127.4 (127.1–127.7)	145.9 (145.2–146.6)	172.9 (171.4–174.3)
First DBP, mm Hg	66.3 (66.1–66.6)	74.6 (74.2–75)	80.7 (80–81.5)	85.4 (84.2–86.6)
Second SBP, mm Hg	108.7 (108.4–109)	126.3 (126–126.5)	144.4 (143.8–145.1)	170.5 (169.3–171.7)
Second DBP, mm Hg	66.1 (65.9–66.4)	74.3 (74–74.7)	80.1 (79.4–80.9)	84.8 (83.6–86.1)
Third SBP, mm Hg	108.0 (107.8–108.3)	125.5 (125.2–125.7)	142.9 (142.3–143.5)	168.5 (167.4–169.5)
Third DBP, mm Hg	66.2 (65.9–66.5)	74.3 (73.9–74.7)	79.8 (79–80.5)	84.2 (82.9–85.6)
Mean first and second SBP	109.4 (109.1–109.6)	126.8 (126.6–127.1)	145.2 (144.5–145.8)	171.7 (170.4–173)
Mean first and second DBP	66.2 (66–66.5)	74.5 (74.1–74.8)	80.4 (79.7–81.2)	85.1 (83.9–86.3)
Mean first and third SBP	108.9 (108.7–109.2)	126.4 (126.1–126.6)	144.4 (143.8–145)	170.6 (169.4–171.8)
Mean first and third DBP	66.2 (65.9–66.5)	74.4 (74.1–74.8)	80.2 (79.5–81)	84.8 (83.6–86.1)
Mean second and third SBP	108.4 (108.1–108.6)	125.9 (125.6–126.1)	143.7 (143.1–144.3)	169.5 (168.4–170.6)
Mean second and third DBP	66.2 (65.9–66.4)	74.3 (74.0–74.7)	80.0 (79.2–80.7)	84.5 (83.2–85.8)
BMI, kg/m^2	26.9 (26.7–27.1)	29.0 (28.7–29.2)	29.8 (29.5–30.1)	29.4 (28.8–30.0)
Current smoker	26.5 (24.9–28.2)	24.2 (22.8–25.7)	20.3 (18.5–22.2)	16.2 (14.0–18.6)
Former smoker	21.9 (20.6–23.3)	26.7 (25.4–28.1)	30.8 (28.7–33.0)	29.9 (26.5–33.6)
Nonsmoker	51.6 (49.7–53.5)	49.0 (47.1–51.0)	48.9 (46.8–51.1)	53.9 (50.2–57.5)
Diabetes, %	4.4 (3.9–4.9)	7.8 (7.1–8.7)	12.2 (10.8–13.7)	17.4 (15.0–20.1)
CVD, %	5.1 (4.6–5.8)	7.2 (6.4–8.1)	12.8 (11.5–14.2)	16.6 (14.1–19.4)
CKD, %	2.7 (2.4–3.2)	5.6 (5.0–6.4)	11.1 (9.7–12.7)	20.7 (17.6–24.2)
Framingham risk >20%	8.9 (8.2–9.8)	16.0 (14.9–17.2)	26.8 (24.9–28.8)	41.3 (38.0–44.7)
Framingham risk 10%–20%	7.9 (7.1–8.8)	16.7 (15.6–17.8)	21.8 (19.8–23.8)	19.0 (16.4–21.9)
Framingham risk <10%	83.1 (81.9–84.4)	67.3 (65.6–69.0)	51.4 (48.8–54.0)	39.7 (36.4–43.1)

Abbreviations: BMI, body mass index; CKD, chronic kidney disease; CVD, cardiovascular disease; DBP, diastolic blood pressure; NH, non-Hispanic; SBP, systolic blood pressure. Values in parentheses are 95% confidence intervals.

tensive, had Framingham 10-year CHD risk equivalents (10-year risk >20% or diabetes, clinical cardiovascular disease [CVD]), or who had CKD all increased as BP category progressed from normal to stage 2 hypertension. The proportion of current cigarette smokers was higher in the normal and prehypertension categories than stage 1 and 2 hypertension categories.

For most individuals, the BP category defined by the first BP remained the same when BP values were averaged (Table II). Among both normotensive and treated hypertensive individuals with a normal BP, ≥90% continued to have BP <120/<80 mm Hg when ≥2 measurements were averaged. Fewer than 10% of individuals were re-classified as having prehypertension and only rarely (<0.2%) as having stage 1 hypertension.

Among nonhypertensive and treated hypertensive patients treated to the prehypertension category based on the first BP, 8.0% to 23.6% were categorized as normal BP based on repeated measurements. The percentages reclassified as stage 1 hypertension were 1.3% to 3.2% (95% CI, 1.0%–3.7% [nonhypertensive]) and 2.6% to 4.2% (95% CI, 1.9%–4.2% [hypertensive treated to prehypertension]).

Among hypertensive patients categorized as having stage 1 hypertension on initial BP, 21.0% to 35.5% were reclassified to a lower BP category on repeated measurements. Among stage 1 hypertensive patients on initial BP, 1.4% to 2.6% (95% CI, 1.0%–3.5%) were reclassified to stage 2 hypertension. In patients with stage 2 hypertension on initial BP, 18.2% to 32.2% were reclassified to a lower BP category on repeated measurements.

For nonhypertensive and hypertensive patients with an initial normal BP, age was not related to persistence in the normal or reclassification to the prehypertension category on repeated measurements (Table III). Among nonhypertensive individuals with an initial BP in the prehypertension category, individuals 40 to 59 years and 60 years and older were less likely to be reclassified as normotensive and more likely to be reclassified as stage 1 hypertensive on repeated measurements than patients 18 to 39 years. However, among treated

TABLE II. Classification of BP by First BP Compared With the Mean of 2 or 3 BP Values

BP Category and First BP	BP Category	Mean First and Second BP	Mean First, Second, and Third BP	Mean Second and Third BP
Normal, No./%	Normal	8315/97.1 (96.7–97.5)	8287/96.7 (96.3–97.1)	8029/93.3 (92.6–93.9)
8553/38.7 (37.5–40.0)	Pre-HTN	238/2.9 (2.5–3.3)	266/3.3 (2.9–3.7)	522/6.7 (6.0–7.4)
	Stage 1 HTN	0/0	0/0	2/0 (0–0.1)
	Stage 2 HTN	0/0	0/0	0/0
Pre-HTN, No./%	Normal	910/13.9 (12.8–15.1)	1232/8.9 (17.6–20.2)	1556/23.6 (22.2–25.1)
6416/30.9 (30.0–31.9)	Pre-HTN	5415/84.7 (83.5–85.9)	5095/79.8 (78.4–81.1)	4663/73.2 (71.6–74.7)
	Stage 1 HTN	91/1.3 (1–1.7)	89/1.4 (1–1.8)	197/3.2 (2.7–3.7)
	Stage 2 HTN	0/0	0/0	0/0
HTN to normal, No./%	Normal	692/94.9 (92.8–96.4)	694/94.5 (92.3–96.2)	665/91.0 (88.0–93.3)
733/3.2 (2.9–3.6)	Pre-HTN	41/5.1 (3.6–7.2)	39/5.5 (3.8–7.7)	67/8.9 (6.6–11.9)
	Stage 1 HTN	0/0	0/0	1/0.1 (0–1)
	Stage 2 HTN	0/0	0/0	0/0
HTN to pre-HTN, No./%	Normal	147/8.0 (6.4–9.9)	234/12.9 (10.9–15.2)	322/17.7 (15.4–20.3)
1753/7.1 (6.7–7.6)	Pre-HTN	1559/89.4 (87.4–91.2)	1476/84.6 (82.4–86.5)	1358/78.0 (75.5–80.3)
	Stage 1 HTN	47/2.6 (1.9–3.6)	43/2.5 (1.8–3.6)	72/4.2 (3.3–5.5)
	Stage 2 HTN	0/0	0/0	1/0 (0–0.3)
Stage 1 HTN, No./%	Normal	0/0	0/0	5/0.2 (0.1–0.5)
3454/14.3 (13.6–15.0)	Pre-HTN	692/21.0 (19.3–22.8)	950/28.0 (25.9–30.1)	1222/35.3 (33.2–37.6)
	Stage 1 HTN	2714/77.6 (75.6–79.4)	2454/70.6 (68.4–72.7)	2136/61.8 (59.4–64.2)
	Stage 2 HTN	48/1.4 (1–2)	50/1.5 (1.0–2.1)	91/2.6 (2.0–3.5)
Stage 2 HTN, No./%	Normal	0/0	0/0	0/0
1732/5.7 (5.3–6.1)	Pre-HTN	1/0 (0–0.1)	2/0.2 (0–0.7)	12/0.9 (0.4–1.7)
	Stage 1 HTN	279/18.2 (15.5–21.1)	427/27.0 (24.1–30.1)	519/31.3 (28.5–34.3)
	Stage 2 HTN	1452/81.8 (78.8–84.5)	1303/72.8 (69.7–75.7)	1201/67.8 (64.9–70.6)

Abbreviations: BP, blood pressure; HTN, hypertension. Values in parentheses are 95% confidence intervals.

hypertensive patients with initial BP in the prehypertensive range, individuals 60 years and older were more likely to be reclassified to the normal BP category based on the mean of the first through third and second and third BP values than the youngest group.

Age was not associated with reclassification of patients with stage 1 hypertension on the initial BP measurement compared with mean BP values. For patients with stage 2 hypertension based on their first BP, patients 60 years and older were more likely to remain in the stage 2 range and less likely to be reclassified to stage 1 hypertension than the youngest group, although differences were significant only for the average of the first and second BP values.

Race/ethnicity was generally not associated with significant differences in reclassification from the BP category determined by the first BP value and the category defined by the mean of repeated measurements (Table IV). However, blacks with initial BP in the stage 1 hypertension category were more likely than whites and Hispanics to remain in the stage 1 range and less likely to be reclassified to the prehypertension category. A similar trend was seen for stage 2 hypertension, although only one comparison was significantly different as defined by nonoverlapping 95% CIs.

Among nonhypertensive patients with an initial BP in the normal category, women were more likely than men to remain in the normal category and less likely to be reclassified to the prehypertension category (Table V). Conversely, among nonhypertensive individuals with an initial BP in the prehypertension category, women were less likely than men to remain in the prehypertension category and more likely to be reclassified in the normal BP group.

For all patients, the odds ratios and 95% CIs are depicted between clinical variables and the likelihood of reclassification to a higher (vs same) or lower (vs same) BP category (Figure 2). The direction of reclassification was determined by comparing the BP category defined by the first BP to the category determined by mean values. Increasing age and higher systolic and diastolic BP values on initial measurement significantly raised the likelihood of reclassification to a lower BP category with repeated measurements. Framingham CHD risk equivalents (10-year CHD risk >20%) were less likely to be reclassified to a lower BP category than those with 10-year CHD risk <10.

Patients with higher initial diastolic BP values were more likely to be reclassified to a higher BP category on the mean of ≥2 BP readings than those with lower initial values (Figure 2). Patients with and than without chronic kidney disease (CKD) were marginally more likely to be reclassified to a higher BP category. Women were less likely than men to be reclassified to a higher BP category.

TABLE III. Impact of Age on Reclassification of BP from the First Measurement to the Mean of ≥2 of 3 BP Readings

Category With First BP				Mean First and Second BP			Mean First, Second, and Third BP			Mean Second and Third BP		
18–39	40–59	≥60		18–39	40–59	≥60	18–39	40–59	≥60	18–39	40–59	≥60
Normal			Normal	97.4	96.7	95.9	97.1	96.2	95.3	94.1	91.8[a]	92.0
5912/59.4 (57.6–61.1)	1960/31.6 (29.9–33.3)	681/10.8 (9.8–12.0)	Pre-HTN	2.6	3.3	4.1	2.9	3.8	4.7	5.8	8.2	8.0
			Stage 1	0	0	0	0	0	0	(2) 0	0	0
			Stage 2	0	0	0	0	0	0	0	0	0
Pre-HTN			Normal	18.1	11.0[a]	9.8[a]	23.8	15.2[a]	14.8[a]	27.8	20.4[a]	20.6[a]
2881/32.6 (31.3–34)	2189/34.8 (33.3–36.3)	1346/20.6 (19.3–21.8)	Pre-HTN	81.2	87.2[a]	88.2[a]	75.6	82.9[a]	83.1[a]	69.9	75.9[a]	75.1
			Stage 1	0.7	1.8[a]	2.1[a]	0.6	1.8[a]	2.2[a]	2.3	3.7	4.3[a]
			Stage 2	0	0	0	0	0	0	0	0	0
HTN to normal			Normal	89.5	96.6	93.6	86.5	95.3	94.9	80.5	92.0	91.5
43/0.5 (0.4–0.8)	277/4.4 (3.8–5.9)	413/6.5 (5.8–7.3)	Pre-HTN	10.5	3.4	6.4	13.5	4.7	5.1	19.5	8.0	8.2
			Stage 1	0	0	0	0	0	0	0	0	0.3
			Stage 2	0	0	0	0	0	0	0	0	0
HTN to pre-HTN			Normal	6.3	7.5	8.6	6.0	11.1	15.5[a]	8.8	15.8	20.7[a]
94/1.1 (0.9–1.4)	556/8.5 (7.7–9.3)	1103/16.6 (15.7–17.6)	Pre-HTN	91.0	89.8	88.8	92.0	85.8	82.4[a]	87.6	79.1	75.6[a]
			Stage 1	2.7	2.6	2.5	2.0	3.1	2.0	3.6	5.0	3.7
			Stage 2	0	0	0	0	0	0	0	0.1	0
Stage 1			Normal	0	0	0	0	0	0	0.7	0.1	0.1
446/5.5 (4.8–6.3)	1086/16.1 (14.8–17.4)	1922/28.4 (27.3–29.5)	Pre-HTN	24.5	22.5	18.1	30.4	28.8	26.1	34.5	36.7	34.3
			Stage 1	74.1	76.3	80.2	67.0	70.3	72.2	59.9	61.2	63.1
			Stage 2	1.4	1.2	1.7	2.6	0.8	1.7	4.9	2.0	2.5
Stage 2			Normal	0	0	0	0	0	0	0	0	0
71/0.8 (0.6–1.1)	371/4.7 (4.1–5.3)	1290/17.1 (15.7–18.6)	Pre-HTN	0.2	0	0	0	0.2	0.2	0.9	0.8	0.9
			Stage 1	30.4	21.5	15.3[a]	39.0	29.8	24.4	42.1	32.6	29.6
			Stage 2	69.4	78.5	84.7[a]	61.0	70.0	75.4	57.1	66.7	69.5

Abbreviations: BP, blood pressure; HTN, hypertension. Values in parentheses are 95% confidence intervals (CIs). [a]No overlap 95% CIs vs age 18 to 39 years; 95% CIs overlapped on all comparisons for patients 40 to 59 years and 60 and older.

DISCUSSION

Hypertension guidelines recommend using the mean of ≥2 BP measurements for clinical purposes, yet most patients undergo only one BP measurement in the usual routine office encounter. Our analysis of NHANES 1999–2008 data was performed to assess the proportion of patients who would be reclassified when the BP category determined by the initial reading was compared with the category defined by the mean of ≥2 of 3 readings. Key findings indicate that: (1) the majority of patients remain in the same category when the first BP value is compared with the mean of ≥2 of 3 values, and (2) clinically significant mismatch is predicted by regression to the mean.

Of chief importance to clinicians is how often stage 1 hypertension is mistakenly identified by a single BP when the mean of 2 or 3 BP values fall in the prehypertensive range, thereby risking unnecessary drug treatment, and how often prehypertension would be misdiagnosed based on a single BP when mean BP values fall in the stage 1 hypertensive range, thereby risking lack of necessary drug treatment. When the use of mean BP readings was compared with a single BP value, overtreatment risk occurred in 21.0% (mean of first and second), 28.0% (mean of first to third), and 35.3% (mean of second and third) of patients. Conversely, lack of needed treatment occurred in 1.3% (mean of first and second), 1.4% (first to third), and 3.2% (mean second and third) of patients. Thus, the risk of overtreatment is approximately 10-fold greater than the risk of undertreatment when the BP category determined by the initial reading is used for clinical decision making.

With three BPs available, regression dilution bias was evident. Two phenomena are noted: (1) the mismatch trend with the first BP occurred in the direction of regression to the mean, ie, low initial BP values tended to rise and higher values to fall; and (2) the mismatch trend was heightened by the weighting of the second and third BPs. Therefore, when the first BP was in the prehypertensive range, there were 1.3% and 1.4% migrations to stage 1 hypertension, respectively, when the first and second BPs and the first through third BPs were compared; and a 3.2% migration to stage 1 hypertension when the second and third BPs were compared with the first prehypertensive BP (Table II). On the other end of the spectrum, when the first BP was in the stage 2 hypertensive range, there were 18.2% and 27.0% migrations to stage 1 hypertension, respectively, when mean of the first and second BPs and mean of the first through third BPs were

TABLE IV. Impact of Race/Ethnicity on Reclassification of BP From the First Measurement to the Mean of ≥2 or 3 BP Readings

BP Category First BP				Mean First and Second BP			Mean First, Second, and Third BP			Mean Second and Third BP		
White	Black	Hispanic		White	Black	Hispanic	White	Black	Hispanic	White	Black	Hispanic
Normal			Normal	97.1	96.8	97.6	96.6	96.2	97.7	92.9	93.3	95.3
3830/37.6 (36–39.3)	1513/33.5 (31.8–35.3)	2878/47.9 (45.6–50.2)	Pre-HTN	2.9	3.2	2.4	3.4	3.8	2.3	7.0	6.6	4.7
			Stage 1	0	0	0	0	0	0	(1) 0	(1) 0.1	0
			Stage 2	0	0	0	0	0	0	0	0	0
Pre-HTN			Normal	13.3	13.7	16.6	18.2	16.8	22.6	23.2	21.5	27.4
3101/31 (29.7–32.3)	1287/29.5 (28.1–30.9)	1802/31.8 (30.2–33.4)	Pre-HTN	85.3	84.3	82.4	80.4	81.3	76.3	73.6	74.7	69.6
			Stage 1	1.4	2.0	1.0	1.4	1.9	1.1	3.2	3.8	2.9
			Stage 2	0	0	0	0	0	0	0	0	0
HTN to normal			Normal	95.1	92.2	98.5	94.6	94.8	97.7	91.2	89.0	94.1
426/3.6 (3.2–4.0)	178/3.7 (3.2–4.2)	117/1.5 (1.1–2.0)	Pre-HTN	4.9	7.8	1.5	5.4	5.2	2.3	8.6	11.0	5.9
			Stage 1	0	0	0	0	0	0	(1) 0.2	0	0
			Stage 2	0	0	0	0	0	0	0	0	0
HTN to pre-HTN			Normal	7.5	9.4	10.0	12.7	12.6	14.8	18.0	15.8	20.3
945/7.6 (7.1–8.2)	454/8.8 (7.9–9.8)	308/3.7 (3.2–4.4)	Pre-HTN	89.8	87.6	88.3	84.6	85.2	82.7	77.6	79.8	76.0
			Stage 1	2.7	3.0	1.6	2.7	2.3	2.5	4.4	4.1	3.7
			Stage 2	0	0	0	0	0	0,	0	0.3	0
Stage 1 HTN			Normal	0	0	0	0	0	0	(4) 0.2	0	0
1784/14.7 (13.9–15.6)	767/16.1 (14.9–17.3)	795/10.4 (9.2–11.8)	Pre-HTN	21.8	16.0	19.9	28.5	22.3	29.4	35.8	29.2	37.8
			Stage 1	76.7	82.5	78.4	70.1	76.1	68.8	61.5	67.7	59.6
			Stage 2	1.4	1.5	1.6	1.4	1.6	1.8	2.6	3.2	2.6
Stage 2 HTN			Normal	0	0	0	0	0	0	0	0	0
809/5.4 (5.0–6.0)	439/8.5 (7.7–9.4)	437/4.7 (3.8–5.6)	Pre-HTN	0	(1) 0.1	0	(1) 0.1	(1) 0.4	0	(6) 1.0	(4) 1.0	(2) 0.5
			Stage 1	18.4	15.7	15.8	28.4	20.1	24.7	32.8	24.7	28.3
			Stage 2	81.6	84.3	84.2	71.5	79.5	75.3	66.2	74.3	71.1

Abbreviations: BP, blood pressure; HTN, hypertension.

TABLE V. Impact of Sex on Reclassification of BP From the First Measurement to the Mean of ≥2 of 3 BP Readings

BP Category First BP			Mean First and Second BP		Mean First, Second, and Third BP		Mean Second and Third BP	
Men	Women	BP Category	Men	Women	Men	Women	Men	Women
Normal		Normal	95.6	98.1[a]	95.0	97.9[a]	89.8	95.5[aa]
3278/31.6 (30.1–33.1)	5275/45.5 (43.9–47.1)	Pre-HTN	4.4	1.9[a]	5.0	2.1[a]	10.1	4.5[a]
		Stage 1	0	0	0	0	(2) 0.1	0
		Stage 2	0	0	0	0	0	0
Pre-HTN		Normal	12.0	17.0[a]	16.2	23.1[a]	20.8	28.1[a]
3919/38.4 (37.1–39.7)	2497/23.9 (22.7–25.1)	Pre-HTN	86.7	81.6[a]	82.4	75.7[a]	75.7	69.3[a]
		Stage 1 HTN	1.3	1.4	1.5	1.2	3.5	2.7
		Stage 2 HTN	0	0	0	0	0	0
HTN to normal		Normal	92.5	96.9	91.7	96.9	89.2	92.5
367/3.0 (2.7–3.4)	366/3.4 (3.0–3.9)	Pre-HTN	7.5	3.1	8.3	3.1	10.8	7.3
		Stage 1	0	0	0	0	0	(1) 0.2
		Stage	0	0	0	0	0	0
HTN to pre-HTN		Normal	7.8	8.1	11.9	13.9	16.3	19.0
861/7.1 (6.5–7.7)	892/7.2 (6.7–7.7)	Pre-HTN	89.6	89.3	85.3	83.9	79.8	76.3
		Stage 1	2.6	2.5	2.8	2.2	3.8	4.6
		Stage 2	0	0	0	0	0	(1) 0.1
Stage 1 HTN		Normal	0	0	0	0	(3) 0.2	(2) 0.2
1858/15.3 (14.4–16.4)	1596/13.3 (12.5–14.1)	Pre-HTN	21.4	20.6	28.1	27.8	34.8	36.0
		Stage 1	77.4	77.7	70.7	70.4	62.1	61.5
		Stage 2	1.2	1.7	1.2	1.8	2.9	2.3
Stage 2 HTN		Normal	0	0	0	0	0	0
737/4.6 (4.1–5.1)	995/6.7 (6.1–7.4)	Pre-HTN	(1) 0	0	(1) 0.2	(1) 0.2	(4) 0.5	(8) 1.1
		Stage 1	19.4	17.4	29.9	25.2	34.6	29.2
		Stage 2	80.6	82.6	70.0	74.6	65.0	69.7

Abbreviations: BP, blood pressure; HTN, hypertension. [a]No overlap 95% confidence intervals between men and women.

compared; and a 31.3% migration to stage 1 hypertension when the second and third BPs were compared with the first stage 2 BP determination (Table II).

Shifting of BP categories using mean BPs was due mainly to the change in systolic BP with repeated determinations, but statistical significance was also attached to mean diastolic BP. Odds ratios for a change in BP category when mean BPs were compared with first BP were most strongly associated with increasing BP (Figure 2).

In addition to the primacy of regression to the mean effect in estimating the mismatch between the first BP and mean BPs in the overall analysis, there was also evidence for a supportive correlary. Aging has a significant effect on the weighted frequency distribution curves for median and 90th percentile systolic pressures comparing populations aged 18 to 29 years and 60 to 74 years in the NHANES III database.[21] In NHANES III, median systolic BP was approximately 115 mm Hg for age 18 to 29 years and 145 mm Hg for age 60 to 74 years. Therefore, regression to the mean is in the direction of normal BP for the younger age group, and in the direction of hypertension for those older than 60. However, the aging effect on BP direction with second and third BPs in the NHANES cohort in our study was not robust. Persistance in stage 1 hypertension comparing first BP and mean BPs for age 18 to 39 years for the three mean categories ranged from 59.9% to 74.1%, which was only slightly less than persistence in stage 1 hypertension for age 60 years and older, ranging from 63.1% to 80.2% (Table III). However, persistence in the stage 2 range was more likely in the older age group with repeated BP measurements. The odds ratio for reclassification to a lower BP category, with mean of ≥2 of 3 BP values for each 10-year increase in age was 9% (CI, 1.05%–1.14%) (Figure 2).

The importance of regression to the mean in assessing BP was apparent in Framingham data. Individuals with the highest BPs on initial examination underwent greater regression to the mean on the second examination than those with less elevated BPs. Through 7 examinations, BPs increased gradually with age in linear fashion, with cardiovascular risk over time best predicted by BP on the second clinical examination.[22] Additional population study evidence confirms that follow-up BPs are necessary to diagnose hypertension when the initial BP is elevated.[23]

STUDY LIMITATIONS

Limitations of this study include differences in BP measurements with NHANES values obtained under a

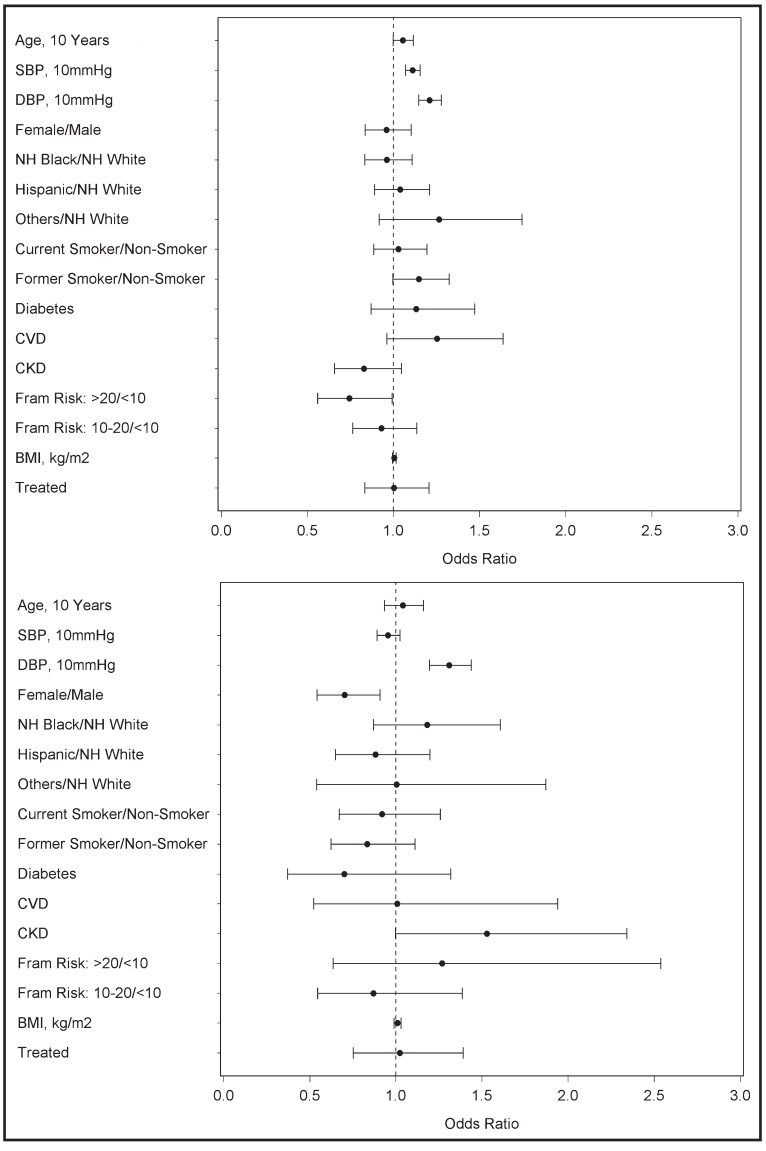

FIGURE 2. The upper panel provides the odds ratios and 95% confidence intervals for the relationship of various clinical variables and reclassification of blood pressure (BP) to a lower category when the mean of 2 or 3 readings was compared with the initial measurement. The lower panel is the same as the upper panel except that the dependent variable is reclassification to a higher BP category when the mean of 2 or 3 BP values was compared with the initial value. SBP indicates systolic blood pressure; DBP, diastolic blood pressure; NH, non-Hispanic; CVD, cardiovascular disease; CKD, chronic kidney disease; Fram, Framingham; BMI, body mass index.

rigorous protocol, whereas methodological errors are common in routine clinical practice. Thus, our findings may not translate fully to office settings where patients are followed over time. For example, terminal digit preference significantly affects manual sphygmomanometer measurements in clinical settings.[23–25] Many other types of observer error are independent of the type of BP monitor used.[26–30] Moreover, NHANES participants characterize a representative cross-section civilian population sample for each examination rather than a longitudinal cohort that participates in multiple examinations. Our report using the NHANES data provides a relatively focused look at a specific clinical question: how does one vs up to three mean BP values impact provider assessment of office BP control on each visit?

CONCLUSIONS

In a system such as NHANES where accurate BPs are obtained, whether repeat BPs to determine control are needed following an initial BP measurement is dependent on regression to the mean effect. Given the fact that many millions of office BPs are performed monthly, it is important to determine where finite health care resources are best applied. An initial BP measurement in the stage 1 hypertension range should

be repeated to assess control because reclassification to a nonhypertensive BP, ie, controlled status, can occur up to 35% of the time. Conversely, when an initial office BP is normal, <0.2% are reclassified to stage 1 hypertension. Even when the initial BP is in the prehypertensive category, only 1.3% to 4.2% are reclassified as stage 1 hypertension. Upward reclassification from a nonhypertensive BP to a level requiring initiation or intensification of treatment is relatively uncommon when reliable BPs occur.

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